

## X-RAY ASTRONOMY

Dr. S. N. Zhang has lead a seven member group (Dr. Yuxin Feng (MIT postdoc, but full-time visiting scientist to Dr. Zhang's group), Mr. Xuejun Sun (UAH research analyst III, on-site at MSFC), Mr. Yongzhong Chen (visiting scholar from IHEP, China), Mr. Jun Lin (UAH graduate student), Mr. Yangsen Yao (UAH graduate student), and Ms. Xiaoling Zhang (UAH graduate student). This group has carried out the following activities: continued data analysis from space astrophysical missions CGRO, RXTE, ASCA and Chandra. Significant scientific results have been produced as results of their work. They discovered the three-layered accretion disk structure around black holes in X-ray binaries; their paper on this discovery is to appear in the prestigious Science magazine. They have also developed a new method for energy spectral analysis of black hole X-ray binaries; four papers on this topics were presented at the most recent Atlanta AAS meeting (all these papers are under revision for ApJ submission). They have also carried Monte-Carlo simulations of X-ray detectors, in support to the hardware development efforts at MSFC. These computation-intensive simulations have been carried out entirely on the computers at UAH. They have also carried out extensive simulations for astrophysical applications, taking advantage of the Monte-Carlo simulation codes developed previously at MSFC and further improved at UAH for detector simulations. One refereed paper and one contribution to conference proceedings have been resulted from this effort. They have also been involved in writing many proposals. The most significant success is winning four proposals of the Astro-E mission (only about 70 US proposals were selected in a stiff competition). Dr. Zhang is also involved as Co-I in some proposed future missions. Currently Dr. Zhang is leading a proposal to NASA, in collaboration with other UAH and MSFC scientists, for a new detector development effort, aiming at producing the best room-temperature semi-conductor X-ray and gamma-ray detectors. Dr. Zhang was one of the organizers of an international meeting in Hong Kong and also gave an invited review at the meeting.

In addition a Physics Department graduate student (Mr. Kim Ong) working under the direction of Professor Z. E. Musielak at the Center for Space Plasma and Aeronomic Research (CSPAR) and Department of Mechanical and Aerospace Engineering and Dr. M. Weisskopf (MSFC) has constructed the first purely theoretical, self-consistent and time-dependent solar wind models using a modified version of the ZEUS code. The models are radially symmetric and the initial atmosphere is magnetized and expanding. The outflow is described by standard Parker's wind solution and the effects of Alfvén waves on the outflow are investigated by solving the full set of ideal and nonlinear MHD equations. In contrast to previous studies, no assumptions regarding wave linearity, wave damping and wave-flow interaction are made. The constructed models naturally account for the backreaction of the wind on the waves and for the nonlinear interaction between different types of MHD waves. For a perturbed wave amplitude about 50-100 km/s, results clearly demonstrate that momentum deposition by Alfvén waves in the solar wind is sufficient to explain the origin of the fast stream in solar coronal holes. Also, a Physics Department graduate student working under the direction of Professor Z. E. Musielak at the Center for Space Plasma and Aeronomic Research (CSPAR) and Department of Mechanical and Aerospace Engineering has: (a) participated in and supported the scientific development of advanced instruments and experimental techniques for X-ray astronomy; (b) participated in and supported a continuing program of balloon and sounding rocket flights, including flight detector

development, ground support equipment development, pre-flight preparation field support, and post-flight refurbishment; (c) supported the analysis and interpretation of scientific data from flight and ground-based experiments; (d) provided scientific and analytical support for AXAF-I with emphasis in the area of scientific instrument calibration and testing.

### **Publications and Presentations**

"RXTE observations of Cygnus X-3", McCollough, M. L. and Robinson, C. R. and Zhang, S. N. and Harmon, B. A. and Paciesas, W. S. and Dieters, S. W. and Hjellming, R. M. and Rupen, M. and Mioduszewski, A. J. and Waltman, E. B. and Ghigo, F. D. and Pooley, G. G. and Fender, R. P. and Cui, W. and Trushkin, S., *New Astronomy Review*, 1998, Vol. 42, 629-632,

"Spectral Transitions in Cygnus X-1 and Other Black Hole X-Ray Binaries, *Astrophysical Journal*", Esin, A. A. and Narayan, R. and Cui, W. and Grove, J. E. and Zhang, S. -N., 1998, Vol. 505, 854-868.

"The Outbursts and Orbit of the Accreting Pulsar GS 1843-02=2S 1845-024", Finger, M. H. and Bildsten, L. and Chakrabarty, D. and Prince, T. A. and Scott, D. M. and Wilson, C. A. and Wilson, R. B. and Zhang, S. N., *Astrophysical Journal*, 1999, Vol. 517, 449-459,

"Discovery of Correlated Behavior between the Hard X-Ray and the Radio Bands in Cygnus X-3", McCollough, M. L. and Robinson, C. R. and Zhang, S. N. and Harmon, B. A. and Hjellming, R. M. and Waltman, E. B. and Foster, R. S. and Ghigo, F. D. and Briggs, M. S. and Pendleton, G. N. and Johnston, K. J., *Astrophysical Journal*, 1999, Vol. 517, 951-955,

"Hard X-Ray Lags in GRO J1719-24", van Der Hooft, F. and Kouveliotou, C. and van Paradijs, J. and Paciesas, W. S. and Lewin, W. H. G. and van Der Klis, M. and Crary, D. J. and Finger, M. H. and Harmon, B. A. and Zhang, S. N., *Astrophysical Journal*, 1999, Vol. 519, 332-335

"BATSE Observations of the Piccinotti Sample of Active Galactic Nuclei", Malizia, A. and Bassani, L. and Zhang, S. N. and Dean, A. J. and Paciesas, W. S. and Palumbo, G. G. C., *Astrophysical Journal*, 1999, Vol. 519, 637-641

"Hard X-Ray Variability of the Black Hole Candidate GRO J0422+32 during Its 1992 Outburst", Van Der Hooft, F. and Kouveliotou, C. and Van Paradijs, J. and Paciesas, W. S. and Lewin, W. H. G. and Van Der Klis, M. and Crary, D. J. and Finger, M. H. and Harmon, B. A. and Zhang, S. N., *Astrophysical Journal*, 1999, Vol. 513, 477-490

"The Kilohertz QPO Frequency and Flux Decrease in Aquila X-1 and the Effect of Soft X-Ray Spectral Components", Yu, W. and Li, T. P. and Zhang, W. and Zhang, S. N., *Astrophysical Journal*, 1999, Vol. 512, L35-L38

"Strong Aperiodic X-Ray Variability and Quasi-Periodic Oscillation in X-Ray Nova XTE J1550-564", Cui, W. and Zhang, S. N. and Chen, W. and Morgan, E. H., *Astrophysical Journal*, 1999, Vol. 512, L43-L46

Malizia, A., L. Bassani, S.N. Zhang, A. J. Dean, W. S. Paciesas and G. G. C. Palumbo, BATSE Observations of the Piccinoti Sample of Arctive Galactic Nuclei, *Astrophysical Journal*, 519, 637, 1999.

van der Hooft, F., C. Kouveliotou, J. van paradijs, W. S. Paciesas, W. H. G. Lewin, M. van Der Klis, D. J. Crary, M. H. Finger, B. A. harmon, and S. N. Zhang, Hard X-Ray Lags in GRO J1719-24, *Astrophysical Journal*, 519, 332, 1999.

Finger, M. H., L. Bildsten, D. Chakrabarty, T. A. Prince, D. M. Scott, C. A. Wilson, R. B. Wilson, and S. N. Zhang, The Outbursts and Orbit of the Acceting Pulsar GS 1843-02=2S 1845-024, *Astrophysical Journal* 517, 449, 1999.

Van Der Hooft, F., C. Kouveliotou, J. van Paradijs, W. S. Paciesas, W. H. G. Lewin, M. van Der Klis, D. J., Crary, M. H. Finger, B. A. Harmon, and S. N. Zhang, Hard X-Ray Variability of the Black Hole Candidate GRO J0422+32 during Its 1992 Outburst, *Astrophyscial Journal*, 513, 477, 1999.

Cui, W., S. N. Zhang, W. Chen, and E. H. Morgan, Strong Aperiodic X0Ray Variability and Quasi-Periodic Oscillationing X-Ray Nova XTE J1550-564, *Astrophysical Journal Letters*, 512,L43-L46, 1999.

Yu, W., T. P. Li, W. Zhang, and S. N. Zhang, The Kitoherztz QPO Frequency and Flux Decrease in Aquila X-1 and the Effect of Soft X-Ray Spectral Components, *Astrophysical Journal Letters*, 512L35-L38, 1999.

Sun, X. and Zhang, S. N. and Cui, W. and Chen, W., Spectral Evolution of XTEJ1748-288 During its Outburst With RXTE Observations, *American Astronomical Society Meeting*, 1999, 195, 6905

Zhang, S. N., Zhang, X., Sun, X., Yao, Y., Cui. W., Chen, W., Wu, X. and Xu, H., Discovery of a three-layered atmospheric structure in accretion disks around stellar-mass black holes, *American Astronomical Society Meeting*, 1999, 195, 12601.

Feng, Y., Zhang, S. -N. Chen, W. and Cui, W., Evolution of the Iron K-alpha Emission Line in the Black Hole Candidate GX339-4 During an Outburst Decay Phase, *American Astronomical Society Meeting*, 1999, 195, 12605

Chen, W., Cui, W. and Zhang, S. N., Black Hole Spin Evolution and Cosmic Censorship, *AAS/High Energy Astrophysics Division*, 1999, 31, 1107

Cui, W., Zhang, S. N., Chen, W. and Swank, J. , Quasi-Periodic Oscillations in Black Hole Candidates, *AAS/High Energy Astrophysics Division*, 1999, 31, 1604

Harmon, B. A., Wilson, C. A., Fishman, G. J., McCollough, M. L., Robinson, C. R., Sahi, M., Paciesas, W. S. and Zhang, S. N., Preview of the BATSE Earth Occultation Catalog of Low Energy Gamma Ray Sources, AAS/High Energy Astrophysics Division, 1999, 31, 2605

Cui, W., Wen, L., Zhang, S. N. and Wu, X. -B., XTE J1550-564, IAU Circular, 1999, 7191, 1.

"The Timing Evolution of 4U 1630-47 during Its 1998 Outburst", Dieters, S. W., Belloni, T., Kuulkers, E., Woods, P., Cui, W., Zhang, S. N., Chen, W., van der Klis, M., van Paradijs, J., Swank, J., Lewin, W. H. G. and Kouveliotou, C., The Astrophysical Journal, Vol. 538, pp. 307-314, 7/2000

"Hard X-Ray Detection of the High-Redshift Quasar 4C 71.07", Malizia, A.; Bassani, L.; Dean, A. J.; McCollough, M.; Stephen, J. B.; Zhang, S. N.; Paciesas, W. S., The Astrophysical Journal, Volume 531, Issue 2, pp. 642-646. 03/2000

"Three-Layered Atmospheric Structure in Accretion Disks Around Stellar-Mass Black Holes", S.N. Zhang, Wei Cui, Wan Chen, Yangsen, Xiaoling Zhang, Xuejun Sun, Xue-Bing Wu and Haiguang Xu, Science, Vol. 287, pp. 1239-1241, Feb. 18, 2000

"Evidence for Doppler-shifted Iron Emission Lines in Black Hole Candidate 4U 1630-47", Cui, Wei; Chen, Wan; Zhang, Shuang Nan, The Astrophysical Journal, Volume 529, Issue 2, pp. 952-960, 02/2000

"Phase Lag and Coherence Function of X-Ray Emission from Black Hole Candidate XTE J1550-564", Cui, Wei; Zhang, Shuang Nan; Chen, Wan, The Astrophysical Journal, Volume 531, Issue 1, pp. L45-L48, 03/2000

The USRA activities are included in a separate report which is submitted as a sub-contract report in the appendix.

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**GRAVITATIONAL PHYSICS RESEARCH**

2001/6/86

The ISPAE members here are UAH employees only. Gravitational physics research at ISPAE is connected with NASA's Relativity Mission (Gravity Probe B - GP-B) which will perform a test of Einstein's General Relativity Theory. GP-B will measure the geodetic and motional effect predicted by General Relativity Theory with extremely stable and sensitive gyroscopes in an earth orbiting satellite. Both effects cause a very small precession of the gyroscope spin axis. The goal of the GP-B experiment is the measurement of the gyroscope precession with very high precision. GP-B is being developed by a team at Stanford University and is scheduled for launch in the year 2001. The related UAH research is a collaboration with Stanford University and MSFC. This research is focussed primarily on the error analysis and data reduction methods of the experiment but includes other topics concerned with experiment systems and their performance affecting the science measurements. The hydrogen maser is the most accurate and stable clock available. It will be used in future gravitational physics missions to measure relativistic effects such as the second order Doppler effect. The HMC experiment, currently